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Comparison of eye movements over faces in photographic positives and negatives

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Abstract. Eye movements were recorded while subjects viewed ordinary portraits and photographic negatives of those portraits. Under both conditions they first studied sixteen portraits and then tried to decide which of forty-eight portraits they had just seen. They made more errors of recognition while viewing negatives, and their fixation patterns were significantly altered: there was a decrease in the percentage of fixations directed to the eyes, nose, and mouth, and an increase for such details as the ears, cheeks, chin, cap, and necktie. There was also a decrease in the ratio of fixations to the most fixated detail compared to the least fixated detail.

1 Introduction

It is more difficult to recognize faces in photographic negatives than in positives (Galper 1970; Galper and Hochberg 1971; Laughery et al 1971; Nelson and Swartz 1971; Phillips 1972; Sorce and Campos 1974). The reason is not clear, for although the faces in negatives are reversed in brightness, the spatial relations are still the same.

Phillips (1972) has noted three explanations that have been proposed for the difficulty with negatives. The first is Sutherland's suggestion that it is due to the predominance of grays in negatives. But Phillips concluded that this hypothesis was not supported by his own experiments using photographs printed only in black and white with no shades of gray.

A second is Galper's (1970) proposal that there is a loss of expression in negatives. Sorce and Campos (1974) did, indeed, find that there is a loss of ability to recognize expression in negatives. Yet using faces constructed with an 'Identi-Kit', Bradshaw and Wallace (1971) found no difference in recognition of positive and negative faces. The Identi-Kit, however, does somewhat limit the projection of expression. The expression explanation seems to be more seriously weakened by McKelvie's findings that, although judgments of expression are based primarily on the brow and mouth (McKelvie 1973), the mouth contributes very little to the representation of a face in memory (McKelvie 1976).

A third explanation is that shadows provide important cues about the architecture of faces, and shadows are hard to interpret in negatives. Along similar lines, one might expect certain other cues, such as color, to improve performance, yet Laughery et al (1971) showed that it does not. Moreover, the difficulties in recognizing faces of other races (Luce 1974; Malpass and Kravitz 1969) show that the presence of shadows cannot be the whole explanation.

Another possible explanation is that observers have difficulty with negatives because they are not looking at the appropriate details of the photograph. Bradshaw and Wallace (1971) concluded that faces are not treated as Gestalten. Just as in viewing other objects, observers tend to cluster their fixations (Kaufman and Richards 1969; Mackworth and Morandi 1967; Richards and Kaufman 1969; Yarbus 1967).

Braine (1965) has reported that the scanning of a face has 'directionality', and Ellis et al (1975) have pointed out that faces are usually reconstructed from top to bottom. As to what features are most important, Howells (1938), in an early study, found that masking the lower part of the face disrupted recognition more than masking the upper part, but more recent studies have concluded that the upper part of the face is more important than the lower part (Goldstein and Mackenberg 1961; Hess and Pick 1974; Laughery et al 1971).

In any event, it may be that in scanning negatives, observers do not fixate the usual details and do not, therefore, pick up their usual information. The situation may be analogous to that found for young children looking at ordinary pictures. Several investigators have found that children exhibit poor scanning strategies (Vurpillot 1968). Although these improve with age (Tronick and Clanton 1971), children generally concentrate their fixations on different areas of a picture than do adults (Mackworth and Bruner 1970), and their scan paths have no clear relation to the shape of the object they are examining (Zinchenko et al, cited by Pick 1964).

It is also possible that observers do not make enough fixations. Loftus (1972) has found that recognition memory for pictures is a function of the number of fixations, and he has concluded that fixation patterns are a basis for inferring how visual information is processed.

The aim of this study, thus, was to see if observers fixate the details of photographic negatives differently from those of photographic positives. Their fixation patterns were analyzed both when they were first trying to learn the photographs and then when they were trying to recognize them.

2 Method

2.1 *Subjects*

Two men and two women (one of whom had the reputation of 'never forgetting a face') volunteered to serve as subjects.

2.2 *Photographs*

The faces used in the experiment were taken from the file of official portraits of physicians and nurses who have served at the Naval Submarine Medical Center. All were in winter uniform, wearing their caps, and identically posed in typical portrait fashion slightly to one side. All the portraits were thus, except for sex differences, identical for pose, clothing, visible hair, and with the usual homogeneity of expression seen in such official portraits. Aside from the occasional presence of spectacles, recognition memory for these pictures thus depended almost completely on facial characteristics. Forty-eight photographs were used, of which twenty-six were of men. Seven of the men and six of the women wore spectacles. Each portrait was prepared both as a positive and a negative 35 mm black-and-white slide.

The slides were projected onto the rear of a ground glass screen placed 110 cm from the subject. The projected slide measured 32 cm wide by 48 cm high, or about 16 deg x 25 deg visual angle. The faces were somewhat larger than life-size and subtended approximately the visual angle to be found when individuals are conversing at a separation of about 90 cm. Some approximate measurements were 5 deg between the eyes, 3 deg between the visible ear and the nearer eye, and 1·5 deg between the mouth and the tip of the nose.

2.3 *Apparatus*

Eye movements were measured with a Biometrics Inc eye-movement monitor, model SGHV-2. The resolution of this device is better than 1 deg in the vertical meridian and a fraction of a degree along the horizontal meridian, well within the limits required by the size of the stimulus photographs. The results were recorded on magnetic tape by a

Hewlett-Packard FM Instrumentation recorder, model 3960. Paper records were made with a MFE X-Y recorder and a Houston Instruments Omnigraphic strip chart recorder.

In order to facilitate the analysis of the records, every photograph was preceded by a calibration slide which projected a fixation spot corresponding spatially to the tip of the nose of the succeeding portrait. The subjects were instructed to fixate each of these slides for a second or two for purposes of calibration before going on the next portrait. They were not told, of course, what the location of the spots corresponded to. Involuntary eye movements brought about by the changing of the slide concealed the relationship, and it was not uncommon for a subject's first fixation to be on something other than the nose.

In addition to these calibration slides, there were another six elaborate calibration slides with seven numbered fixation points corresponding to seven selected features on the portraits which followed them. These six slides were interspersed at intervals throughout the session. The subjects were instructed to fixate each of the seven fixation points for about a second when these slides appeared. The existence of a large number of these calibration records made it an easy matter to specify the location of the fixations on the photographs.

2.4 *Procedure*

Each session consisted of a learning phase followed immediately by the recognition phase. Sixteen photographs (seven men and nine women) were selected randomly for the learning series. Two of the men and two of the women wore spectacles. The subjects were told that they would see a set of faces (they were not told how many), after which they would be shown a second set of faces. Their task would be to report whether or not each photograph in the second set had been in the first set. All sixteen photographs from the learning series were included in the recognition series, but the subjects were not told this.

The subjects had two sessions, one in which they saw the positives and another in which they saw the negatives. One man and one woman viewed the positives first; the other two subjects viewed the negatives first. They were not told that the portraits were always presented in the same order, or, indeed, that both positives and negatives would be used. One subject who viewed the positives first and one who viewed the negatives first were retested a week later. The other two were retested three to four weeks later respectively.

The subject controlled the rate of presentation. He was permitted to examine each photograph as long as he wished, both to memorize the faces and to recognize them. Each session lasted about 15 min.

3 Results

3.1 *Accuracy of recognition*

Every subject made more errors with the negatives (paired $t_3 = 2 \cdot 64$; $p < 0 \cdot 10$). Of the forty-eight judgments for each set of photographs, they made a total of nineteen errors when viewing the positives and thirty-seven errors on the negatives (table 1). With the positives, fourteen of the errors were incorrect reports that the photographs had been presented before. Five of the errors were a failure to recognize a previously presented photograph. With the negatives, twenty-one errors were incorrect 'recognitions' and sixteen were failures to recognize.

3.2 *Number of fixations*

Every subject made more fixations per photograph on the average when studying negatives than positives (paired $t_3 = 2 \cdot 62$; $p < 0 \cdot 10$). The mean values are shown in table 2. They made more fixations per photo during the learning series than during the recognition phase ($t_3 = 2 \cdot 35$; $p < 0 \cdot 10$), both for positives and for negatives.

Interestingly, the subjects made relatively many more fixations on the negatives than on the positives during the learning phase than during the recognition phase. Apparently they used more time to memorize the negative but not much more time to make recognition decisions about them.

Table 1. Number of errors in recognition of photographs of men and women.

	Positives		Negatives	
	yes[a]	no[b]	yes	no
Men	8	2	18	3
Women	6	3	13	3

[a]Indicates an incorrect report that the photograph appeared in the learning series.
[b]Indicates a failure to recognize a photograph which appeared in the learning series.

Table 2. Mean number of fixations per photograph.

	Number of photographs	Number of fixations	
		positives	negatives
Learning	16	19·3	28·8
Recognition	48	12·1	14·4
Mean	64	14·9	19·8

3.3 *Distribution of fixations*

3.3.1 *Positives vs negatives.* The fixations made by the subjects have been grouped into these categories: eyes; nose; ears, including sideburns and visible hair around the ear; cheeks and chin; and the cap and necktie. Figure 1 shows the fixation areas.

Figure 1. Outline of a typical photograph showing fixation areas. The areas were tailored to each photograph.

There were virtually no fixations outside these areas to the blank background or the black, featureless uniform (the lapel outlines were barely visible). The fixations to the various areas of both positives and negatives during both phases of the session are given in table 3 as percentages of the total number of fixations, which facilitates the comparison of major interest, the proportions of fixations made to the various areas on positives and negatives.

An analysis of variance of the learning phase showed that the interaction between percentage of fixations to the various features and the type of photograph (positive or negative) was highly significant ($F_{5,15} = 7 \cdot 25$; $p < 0 \cdot 001$). To determine which pairs of means were significantly different, the percentage of fixations for each subject to a given area on each positive was compared to his fixations to that area on the negative of the same photograph. Paired t tests showed that the increase in fixations to the cap in the negatives was significant for every subject, and the increase in fixations to the cheeks in the negatives was significant for two subjects. The increase in fixations to the ears and the decrease to the eyes, nose, and mouth were significant for only one subject, but similar trends were exhibited by two other subjects in each case. Paired t tests across all subjects yielded significant critical ratios for four of the six changes.

During the recognition phase, a similar pattern occurred. An analysis of variance again showed that the interaction between type of photograph and fixations to the various features was significant ($F_{5,15} = 2 \cdot 95$; $p < 0 \cdot 05$), and nine of the changes for individual subjects were significant, according to paired t tests. Paired t tests across all subjects again yielded significant critical ratios for four of the six changes.

Table 3. Percentages of fixations to various details of the photographs for each subject.

		Eyes	Nose	Mouth	Ears	Cheeks	Cap
Learning							
TP	positive	26	35	16	9	12	1
	negative	27	39	8*	9	11	5*
HL	positive	16	59	16	0	9	0
	negative	13	54	12	2	15*	3**
HP	positive	19	31	10	9	15	15
	negative	18	28	6	10	16	21*
MM	positive	38	30	8	16	5	3
	negative	27*	16**	4	23*	18**	10**
Mean	positive	24	38	12	9	12	5
	negative	22	35*	7**	10	15*	10**
Recognition							
TP	positive	35	30	20	6	8	1
	negative	35	28	12**	13**	11	2*
HL	positive	10	56	21	2	10	1
	negative	8	52	25	3	12	0
HP	positive	24	35	12	7	14	7
	negative	20*	35	10	6	23**	7
MM	positive	43	35	11	5	4	2
	negative	41	26**	5**	15**	8**	4
Mean	positive	28	39	16	6	9	2
	negative	26	35*	13*	9**	13**	3

$^*p < 0 \cdot 05$; $^{**}p < 0 \cdot 01$.

3.3.2 *The first six fixations.* The preceding results show that when looking at negatives rather than positives, subjects tend to make more fixations on peripheral details of the photograph that would seem to provide relatively little information, such as the cheeks, chin, and cap. It is possible, however, that since subjects make more fixations when viewing negatives, these less informative fixations were made only after the viewer had examined the primary details of the photograph.

To see if the outlying portions of the photographs were examined as an afterthought or if the presumably less informative fixation patterns appeared immediately, the fixation patterns appeared immediately, the fixation patterns were analyzed for only the first six fixations in each photograph. The results, shown in table 4, are similar to the results of the analysis of the total number of fixations, but an analysis of variance showed that for the learning phase, the interaction of type of photo and distribution of fixations was not significant. The interaction was significant, however, for the recognition phase ($F_{5,15} = 13{\cdot}09$; $p < 0{\cdot}001$). Again, there was a decrease in the mean percentage of fixations to the eyes, nose, and mouth and an increase in the mean percentage of fixations to the ears, cheeks and cap. Paired t tests were calculated for the changes for each subject. Although the significant changes occurred mostly in the results of one subject, a tendency for an increase in fixations to the ears, cheeks, and cap and a decrease in fixations to the nose—the most heavily fixated detail—appears in the unrounded data for all subjects. Paired t tests calculated across subjects yielded significant critical ratios in the case of the nose and ears. Thus, the increase in fixations to the less informative parts of the negatives tends to begin early.

Table 4. Percentages of fixations to various details of the photographs for the first six fixations by each subject.

		Eyes	Nose	Mouth	Ears	Cheeks	Cap
Learning							
TP	positive	34	26	18	14	8	0
	negative	27	49	6	7	9	1
HL	positive	18	49	28	0	5	0
	negative	15	66	11	0	8	0
HP	positive	23	52	10	8	2	4
	negative	25	42	9	3	8	13
MM	positive	43	39	5	13	1	0
	negative	54	25	0	14	1	6
Mean	positive	30	42	15	9	4	1
	negative	30	46	6	6	6	5
Recognition							
TP	positive	43	32	18	4	3	0
	negative	37	31	11*	12**	9	0
HL	positive	8	59	20	2	11	0
	negative	8	54	23	3	12	0
HP	positive	29	41	11	8	8	3
	negative	29	40	9	9	9	4*
MM	positive	45	43	8	1	3	0
	negative	45	29**	4*	13**	6*	3*
Mean	positive	31	44	14	4	6	1
	negative	30	38*	12	9**	9	2

$^*p < 0{\cdot}05$; $^{**}p < 0{\cdot}01$.

3.3.3 *Sex differences.* It was unlikely that we would be able to discern any differences between the performance of only two male and two female subjects, and we did not. There was, however, a difference between the fixations of the subjects when they viewed photographs of men and women during the recognition phase. Both the male and female subjects made significantly more fixations on the hair visible around the ears of the women than around the same area of the men, both when viewing positives (7·9% vs 4·8%; $t_{182} = 2{\cdot}48$; $p < 0{\cdot}02$) and negatives (10·8% vs 7·4%; $t_{182} = 2{\cdot}14$; $p < 0{\cdot}05$). This is reasonable, since there are somewhat greater differences in the hair styles of women than men, and more information can be gained from women's hair. There were no other significant differences.

3.4 *Effect of spectacles*
Eye glasses were the only systematic artifacts in the portraits. We therefore examined the results to see if the presence of spectacles aided in the recognition of the faces. We computed the percentages of errors as follows. For example, nineteen of the men did not wear eye glasses. The four subjects therefore had seventy-six opportunities to judge these photographs. They made six errors, which amounts to 8% of their judgments.

The presence of glasses did not improve the recognition of faces in the positive. In photographs of men, the error rate was 8% without glasses and 14% with glasses. For photographs of women, there were 11% errors without glasses and 8% with glasses.

With the negatives, the error rate was less with glasses for photographs of both men (22% vs 14%) and women (20% vs 13%), but the differences were not significant.

3.5 *Fixation duration*
We have estimated the mean fixation duration by selecting at random four of the slides in the learning series (two men and two women) and eight slides in the recognition series (four men and four women) and averaging the durations of all fixations made by the subjects in viewing those photographs.

Mean fixation duration was significantly longer during the learning phase than the recognition phase (296 ms vs 264 ms; $t_{90} = 21{\cdot}0$; $p < 0{\cdot}05$), but there was no significant difference between fixation duration for positives and negatives (286 ms vs 266 ms) or when viewing photographs of men and women (269 ms vs 262 ms).

4 Discussion
A number of investigators have concluded that eye fixation patterns may be regarded as an observable basis for inferring internal processing of visual information (Loftus 1972; Monty et al 1975). Since we would expect such processing to be a stable characteristic in an individual, fixation patterns should also be stable. The present results show that indeed they are. The mean percentages of fixations on the various details of the facial photographs, whether in positives or in negatives, and whether during the learning or during the recognition phase, were remarkably similar. Although there were significant differences from one condition to another, the overall impression is nevertheless one of a reliable and stable phenomenon. The rank orders of the fixations over the various features are almost always the same. Presented with a series of similar stimuli, the subjects scrutinized them in a predictable manner, spending a certain amount of time on each feature within rather narrow limits. The similarity was more noticeable than the changes when viewing conditions changed or the subjects were faced with a different task.

Nevertheless, there were significant changes. As expected, recognition of faces was more difficult in negatives than in positives, as evidenced by both errors and number

of fixations. And as predicted, the distribution of fixations changed. During viewing of the negatives, the percentage of fixations to the eyes, nose, and mouth declined relative to the percentages during viewing of the positives, during both the learning and the recognition phase, while the percentage of fixations to outlying portions of the photographs increased. This led to what might be termed diffuseness in the eye movements: first, the percentage of fixations to what can be considered the less informative details of the photographs increased; second, the ratio of the highest to the lowest percentages of fixations declined. For example, during the learning phase with the positives, there were more than eight times as many fixations to the most frequently fixated detail (the nose) as to the least fixated detail (the cap), whereas with the negatives this ratio declined to only 4·7.

It is difficult to say what the relative importance of the various facial details is, although it is tempting to consider the central details, the eyes, nose, and mouth, the important features in recognition, and the more peripheral details, such as the cheeks, ears, and chin, the less important features. We can be certain of one thing, however: no useful information could be obtained by scrutinizing the officer's medallion on the cap; they were all identical.

Bradshaw and Wallace (1971) concluded from their study that faces are recognized by a repetitive, sequential scan without elimination and replacement of rejected, unimportant features. We would add that not only are unimportant features not replaced, but in situations in which recognition is difficult, the unimportant features receive additional attention.

The effect of spectacles has been examined by McKelvie (1976). He found that subjects were less confident about their judgments of faces with spectacles and spent more time looking at them, but they were remembered as well as the faces without spectacles. Our results confirm his findings. Our subjects also made more fixations to photographs containing spectacles, but there were no differences in their recognition rates.

Loftus (1972) has found that recognition of photographs is a function of the number of fixations: the more fixated pictures were better remembered. In the present results there was an increase in errors of recognition with negatives despite the fact that significantly more fixations were made to them. This raises the question, was the increase in fixations confined primarily to the peripheral portions of the photographs, thus essentially rendering them relatively less useful? When analyzed for each subject, the total number of fixations to the eyes, nose, and mouth remained almost constant for one subject, increased markedly for another, and declined for the other two subjects. The subject with the greatest increase in these central fixations had the highest error rate and the largest increase in errors on negatives relative to the positives. There was, therefore, no relation between number of fixations and errors. These conditions were, of course, quite different from Loftus's: he had a wide variety of pictures, whereas our photographs were all essentially the same.

Fixation duration has been considered to give some indication of cognitive processing. Tinker (1951) found differences in fixation duration for different kinds of reading material, and we have previously found that fixation duration is significantly less for uncoded dials than for those coded by shape or color (Luria and Strauss 1975). In the present experiment, fixation duration was significantly longer when the subjects were studying the photographs than when they were trying to recognize them. On the other hand, there were no significant differences in fixation durations for negatives and positives, which conforms with the results of Bradshaw and Wallace (1971), who also found that negatives were processed as rapidly as positives.

A central question is whether the altered pattern of fixations on the negatives leads to the greater error rate, or whether both are simply a reflection of the subjects' difficulties in processing the negatives. One current viewpoint of perceptual processing is that certain fixation patterns lead to recognition of a given stimulus (Noton and Stark 1971a, 1971b). Since the analysis of the first six fixations shows that the altered pattern of fixations begins to appear very early, it is possible that recognition is impaired because of the absence of the usual fixation patterns. But this still leaves the question of what produces the altered fixation pattern. Olson and Fieman (1975) found that in viewing ambiguous stimuli which could be perceived as different figures, subjects exhibited different scan paths for different phenomenal organizations. They concluded that what the observer saw determined where he looked.

In the present results, although all subjects exhibited both an increase in errors and an increase in fixations to the periphery when viewing negatives, there was no correlation between the increase in the number of errors and the increase in the percentage of fixations to the periphery (either for the total number of fixations or the first six fixations). In view of this lack of correlation, it would seem that the increased errors were not caused by the more diffuse pattern of eye movements, but that both are a reflection of the difficulty in processing negatives.

The subject who had the reputation for remembering faces did, in fact, turn out to make the fewest errors. In analyzing her eye movements, we were struck by the fact that she often made only a very few fixations, often in an astonishingly constricted pattern. Carey and Diamond (1977) have concluded that adults and older children encode configurational aspects of faces, whereas younger children must instead encode isolated features. The sparse and constricted pattern of eye movements of our best subject suggests the possibility that among adults, only the best perceivers are likely to treat faces as Gestalten, whereas the poorer perceivers try to encode specific details. And when the task becomes more difficult, there is a change in the details which the perceivers attempt to encode. The contrast reversal may distract them from the small subtle details which are normally important in recognition and which they usually attend to, and they may now begin to attend to more gross details, such as the cap or the ears, which are less affected by the reversal in contrast but which provide less useful information.

Perhaps as individuals become more experienced in viewing negatives, there are changes in fixation patterns similar to the changes reported for children as they grow older. It would be interesting to compare the eye movements of subjects after various amounts of practice.

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